INVESTIGATION AND ANALYSIS OF MECHANICAL PROPERTIES OF TIG WELDED SPECIMEN DSS/DSS AND CORTEN-A ARC WELDED JOINTS OF DUPLEX STAINLESS STEEL UNS S32205

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Abstract— In this welding process the study was conducted by using the TIG (Tungsten Inert Gas) welding technique. TIG is generally used in, such as car, rail, manufacturing, automotive and chemical industries. Duplex Stainless steel (UNS S32205) is used in industries as an important material, because of its excellent corrosion resistance, higher yield strength and hardness. In the paper we understood the effect of tungsten inert gas welding by varying input process parameters such as gas flow rate , welding current and welding speed, that are influences on mechanical properties such as strength of weld joint, microstructure and hardness . The experimental provides better weld quality, higher productivity and comparison of Activated TIG welding with TIG welding Activated TIG welding can increase the joint penetration. SiO_2 is used as a flux in this work and comparing weld joint penetration and weld depth to-width ratio. By using best clamping method, the angular distortion of weld plates has been avoided.

Index Terms— Welding, Duplex Stainless Steel UNS S32205, Microstructure, Universal Testing Machine, hardness, Tungsten Inert Gas Welding, Tensile Strength.

1 INTRODUCTION

The Tungsten inert gas welding (GTAW) is an electric arc welding process, in which the fusion energy is produced by an electric arc burning between the work piece and the tungsten electrode. During the welding process the electrode, the arc and the weld pool are protected against the damaging effects of the atmospheric air by an inert shielding gas. By means of a gas nozzle, the shielding gas is lead to the welding zone where it replaces the atmospheric air. Background of TIG welding was, like MIG/MAG developed during 1940 at the start of the Second World War. TIG's development came about to help in the welding of difficult types of material, example aluminium and magnesium. The use of TIG today has spread to a variety of metals like stainless mild and high tensile steels. Arc welding is a technique to melt and join different materials that is widely used in the industry. The gas tungsten arc welding (GTAW) process is sometimes referred to as TIG, or heliarc. Under the correct welding conditions, the tungsten electrode does not melt and is considered non-consumable. To make a weld, either the edges of the metal must melt and flow together by themselves or filler metal must be added directly into the molten pool. Filler metal is added by dipping the end of a filler rod into the leading edge of the molten weld pool. Most metals oxidize rapidly in their molten state. To prevent oxidation from occurring, an inert gas flows out of the welding torch, surrounding the hot tungsten and molten weld metal shielding it from atmospheric oxygen. GTA welding is efficient for welding metals ranging from sheet metal up to 1/4 in.

The eye-hand coordination required to make TIG welds is very similar to the coordination required for oxy-fuel gas welding. Although most other welding processes are faster and less expensive, the clean, neat, slag-free welds GTAW produces are used because of their appearance and ease of finishing. The TIG welding process is so good that it is widely used in the high-tech industry applications such as, nuclear industry, aircraft, food industry, maintenance and repair work and some manufacturing areas [1, 2].TIG welding is a process that uses a power source, a shielding gas and a TIG hand piece. An electric arc is then created between the tungsten electrode and the work piece. The tungsten and the welding zone are protected from the surrounding air by a gas shield (Inert gas). The electric arc can produce temperatures of up to 19,400 ^{0}C and this heat can be much focused local heat.

Mukesh, Sanjeev Sharma [1] investigated on mechanical properties of austenitic stainless steel 202 during tungsten inert gas welding. Three input parameters varied at three levels and nine experiments were performed based on L9 orthogonal array.The specimen size was 100x50x6 mm with square edge butt joint. Tensile strength is calculated experimentally, microhardness is found by diagonals of indent formed by pyramid shaped diamond indenter on the specimen. They found that highest tensile strength is 0.595 KN/mm^{2} at a welding current 210 Amps,gas flow rate 14 L/min and welding speed of 190 mm/sec .The specimen is rubbing with emery paper of size 400, 600, 1000 and 2000 and then cleaned with acetone solution. The maximum micro hardness is 80.473 HV at welding current of 210 Amps, gas flow rate of 12 L/min and welding speed of 180 mm/sec. ANOVA analysis was per-formed for analysis purpose that shows current is significant parameters that mostly influence tensile strength and micro hardness.

Vijay Gautam [2] studies process parameters for tungsten arc welding of aluminum alloy AA1100 using AC wave using argon as inert gas. Tensile properties of parent metal and weld part were determined as per ASTM-E8M. Taguchi approach was applied to find parameters which will yield better tensile strength.It hasfound that tensile strength was maximum at 65 Amps, on further increase of current would cause oxidation of tungsten and causing its contamination. Maximum strength as found at 10 L/hr, if there is excess flow could cause cooling and turbulence in weld pool.The welding speed (2.5 mm/s) is optimal for proper fusion and strength. After conducting a con-firmation test to verify strength by using optimal conditions, and found that strength is 85.78 MPa, it is within the limit com-pared to calculated value 91.35 MPa.

N. Arunkumar, P. Duraisamy and S. Veeramanikandan [3] evaluated the tensile, bend and hardness properties of austen-itic stainless steel SS347H, T91 and T22 by metal inert gas welding and tungsten inert gas welding.The tube weld of 54mm outer and 50mm of inner diameter and compared metal inert gas and tungsten inert gas welding. In tensile test he found that tungsten inert gas welding exhibited more strength than metal inert gas welding, approximately 21%. For hard-ness test vicker hardness testing machine was used and found that GTAW produced weld is harder than GMAW(gas metal arc welding), hardness are 270 VHN and 245 VHN for T22 and T91, 293VHN and 197 VHN for T91 and SS .The bend test was performed to evaluate ductility and goodness of weld joint. He found that by selecting proper wire feed, current can remedy wire stub, porosity can be decreased by low hy-drogen welding, increasing gas flow and heat input and clean-ing joint faces. Undercut can be rectified by low travel speed, correct voltage and clean weld surface. Excessive penetration can be rectified by proper alignment of tubes of weld joint.

Kundan kumar and Somnath chttopadhyaya [4] has investi-gated on input variables (current, voltage, travel speed) and output parameters (reinforcement height, weld bead width, metal deposition rate) of tungsten inert gas welding on stain-less steel 304L material of size 150x50x4.8 mm and observed that the error between the experimental result

parameters and pulsed current dura-tion as no significant effect on bead parameters.

Pawan Kumar, Kishor Purushottamrao, Sashikant Janarda [9] has studied the effect of process parameters of pulsed current tungsten inert gas welding on aluminum alloy6061 using si-nusoidal AC wave with argon and helium gas mixture. From the study they have found that pulse current pulse duty cycle, frequency, percentage of helium in argon plays an important role on microstructure, and hardness of weld, Pulsed current plays major role in all of them. Lower micro hardness was ob-served in the weld zone because of using filler rod, dendrites solidified microstructure and segregated phase. It is also ob-served that the pulsed parameters play an important role in development of fine microstructure.

Ratnesh K Shukla, Pravin K Shahhas[10] has done investiga-tion on micro structure, hardness distribution, tensile proper-ties and fracture surface morphology on tungsten inert gas welding and friction stir welding of weld butt joint of 6061 T6 aluminum alloy. They used $AlSi_5$ as filler material, argon as shielding gas, 6061 T6 of 150x60x4 mm size, for friction stir welding rotating tool assembly at 1000-rpm rotation, CNC mill-ing with motor of 11KW is used. They used optical microscope for microstructure and Vickers hardness for hardness of weld material. They found that very fine, equiaxed grain in FSW; this may be due to dynamic recrystallisation. TIGS welding contain dendritic structure this may be due to fast heating of base metal and fast cooling of molten metal. The percentage of elongation of TIG joint is lower than FSW, FSW exhibited higher ductility compare to TIG, FSW joint has higher strength value of 51% of base metal and TIG of 44.5%. Microhardness in FSW is more than TIG and different at four different points of FSW joint.

Nanda naik korra, M Vasudevan, KR Balasubramanian [11] has studied the effect on weld bead geometry of duplex stain-less steel alloy 2205 of activated tungsten inert gas welding process parameters. The current, torch speed and arc gap as input process parameters. The output parameters are depth of penetration, bead width, bead height and aspect ratio. ANOVA analysis was used for development of mathematical models and found that higher current, lower torch speed and lower arc gap gives maximum depth of penetration, higher current, higher arc gap and lower torch speed increases bead width. Higher current, low torch speed and low arc gap gives higher aspect ratio.

Hsuan-Liang Lin and Tong-Min Wu [12] have done experiment on effect of flux and process parameters of Inconel 718 alloy in tig welding. The work piece of 50x100x6.5 mm dimension and flux materials are Sio_2, NiO, MoO_3, Cr_2O_3, TiO_2, MnO_2, ZnO and MoS_2 and flux is mixed with methanol to make paint like consistency. It was found that the depth to width ratio of weld precoated with mixed component flux.It increase with single component flux, with the oxide 50% SiO_2 + 50% MoO_3 being more significant, the fluxes SiO_2, 50%SiO_2 +50%MoO_3 and 50% SiO_2 + 50% MnS_2 have more effect on the voltage, hot cracking was tested by spot varestraint test and found that hot cracking resistance is more in activated TIG compair to con-ventional TIG.

The most significant parameter for depth to width ratio of weld are welding current, speed, electrode angle, in addition a mixed component flux has most effect on penetration and hot cracking of inconel178 alloy.The present work deals with to find best influence of process paramenters on mechinal prop-erties and microstrutues of weld metal on Duplex stainless steel (2205) material using L9 Orthogonal array desing of ex-periments.

2 METHODOLOGY ANDMATERIAL. In this work, Duplex Stainless Steel (2205) alloy of dimension plates 200x75x6mm was taken and the number of pieces was 18. TIG was performed, the number of experiments were nine. The process parameters are root gap, current, electrode and gas flow rate. The DSS2205 (18) metal pieces of plates 200x75x6mm and cleaned the surface of the plates and all the four edges of rectangular shaped metal plates are properly finished. Chamfering is done for the better penetration of depth and 2 to 4 mm of chamfering was taken. The Welding is performed with a TIG apparatus on the metal plates by using filler rod ER 316 according to given parameters. L9 orthogonal array is used to perform design of experiments via Taguchi method. The work pieces are wired cut into required shape on EDM wire cut machine for conducting Tensile strength test, hardness test, microstructure test and penetration. For Acti-vated TIG procedure is same as conventional experiments performed is three. DSS 2205 six met-al pieces are taken and welding is performed.The chemical composition of the base metal and filler rods are given in table

Base Metals	Types of Weld Joints	Metal Grades
DSS/DSS	Similar	AISI 2205/ AISI 2205
DSS/Corten-A	Dissimilar	AISI 2205/ASTM A242

DSS/CRS	Dissimilar	AISI 2205/IS 513_2008CR2_D
DSS/HRS	Dissimilar	AISI 2205/IS 2062:2011

Types of Material Used:

Corten-A or High Strength Low Alloy Steel (HSLA) Corten-A is a strip mill product. The chemical composition of Corten-A has been designed to provide a relative resistance to atmospheric corrosion, in particular for urban environments. Therefore, it can be used even without painting; in this case, a thin layer of stable oxides will be formed which is preventing further corrosion inside. The chemical composition of Corten-A steel has been mentioned below in Table 3.6

Table 3.6 Chemical Composition of Corten-A by % Weight

Material	**Mn**	**Cu**	**Nb**	**Al**	**Fe**
ASTM A242 Corten-A	0.349	0.380	0.008	0.03	Balance

Material	**C**	**Si**	**P**	**S**	**Mn**	**N**	**Al**	**Fe**
HRS	0.23	0.4	0.045	0.045	1.5	0.012	0.02	97.748

behavior of Corten-A in three commercially available surface finish conditions are bare metal, patinated and patinated/waxed- was studied concerning the exposure to rain. Under leaching rain exposure condition, the bare metal shows, as expected, a higher mass variation and metal release compared to the pre-patinated one. However, the metal release in the pre-patinated samples, even if lower than in bare steel, is still significant, indicating a poor protection of the artificial patina towards alloy dissolution. Moreover, waxing does not affect this behavior. The characterizations of the patina give a non-negligible amount of chlorine, partly leached away during the exposure, but partly affecting the stability of the patina [62].

Hot Rolled Steel IS 2062

Hot Rolled Steel conforming to grade IS 2062 was used in this experiment as one of the dissimilar metal. Mainly Hot Rolled Steel (HRS) is used in the fabrication of railway and automotive bodies due to their good weldability. The Hot Rolled Steel (HRS) contains carbon and manganese which ensures good weldability. The HRS is strengthened by microalloying with elements like niobium, vanadium and titanium separately as required to achieve high strength to weight ratio, better formability, weldability and toughness [82]. In this paper, an effort is made to explore the feasibility of fabricating dissimilar welding of DSS/HRS, due to the current trend of using Stainless steel in the railway coach bodies due to their aesthetic appeal and durability. The chemical composition of Hot Rolled high tensile structural steel conforming to grade IS 2062 has been mentioned in Table 3.7

Table 3.7 Chemical Composition of Hot Rolled Steel by % Weight

Equipment Details

Equipment Name : EDAX AND SEM ANALYSER

Model Name : QUANTA 200/ FEI

Magnification Range: 20X to 1, 00,000X

Application : Chemical Composition for Metals and Non-Metals

Experimental Procedure

The experimental setup comprised of, TRIDENT 4009 model GTAW machine with 2 % thoriated tungsten electrode and manual welding technique with a root gap of 1.2 mm. The 2 mm thick tailored blanks of Duplex Stainless Steel (DSS) and HRS were used in this experiment. The sheets of size 150mmx250mm were square butt welded using Gas Tungsten Arc Welding (GTAW) process. The weldments were fabricated with butt joint configuration using E 309LT-1 electrode as filler metal. The welding process parameters used were 16V, 55 Ampere. Suitable fixtures and argon shielding were provided to obtain defect-free joints. The average values of tensile strength 340Mpa mentioned in Table 6.5 and the standard deviation calculated for the samples as 4.35 @ 95% confident level for DSS/HRS samples.

4.6 Experimental Investigation of DSS/Cold Rolled Steel Joints

The purpose of this study is to evaluate the mechanical and metallurgical properties of dissimilar metal weld joints between DSS/CRS by Gas Tungsten Arc Welding (GTAW) process

4.6.1 Experimental Procedure

The cut plates of size 2mm x 150mm x 250mm sizes of both DSS/CRS were kept together with 1.2 mm root gap and the plates were tack welded followed by a run weld. Clamps were used to align and hold the plates together to avoid misalignment and distortion. Welding was carried out by means of GTAW with argon as the shielding gas. After welding, specimens were cooled in the air. 10 samples were made and finally 2 samples selected for the experimental investigation based on the visual inspection parameters like weld appearance and uniform bead width. The average values of tensile strength 308Mpa mentioned in Table 6.7 and the standard deviation for the samples calculated as 3.6 @ 95% confident level for DSS/CRS samples. The welding conditions and process parameters used are

Thickness of Specimen [mm]	Joint Design	Flow rate [Litres / minute]	Welding Position	Current [Amp]	Voltage [V]	Filler feed rate [mm/sec]
2.0	Butt Joint	7	Down hand	55	16	0.5

parameters are Voltage (16.49 %), Current (16.46 %) and the error factor (6.66 %) shown in Table 5.4

Run	Voltage(Volt)	Current(Amp)	Filler feed rate(mm/sec)	Ultimate tensile strength in Mpa
1	16	55	0.5	466
2	16	55	0.4	473
3	16	80	0.7	451
4	15	65	0.4	467

5	15	65	0.7	445
6	15	80	0.5	452
7	13	55	0.7	448
8	13	65	0.5	463
9	13	80	0.4	454

Table 6.4 Tensile Test Values - DSS/Corten-A Weld Joint

Test Parameters	Observed Values
Gauge Thickness (mm)	1.80
Original Width (mm)	18.75
Original Cross Sectional Area (mm2)	33.75
Ultimate Tensile Load (KN)	16.26
Ultimate Tensile Strength (Mpa)	482
Fracture Location	Corten-A steel

5.CONCLUSION

The present work is aimed at experimental analysis of TIG welding by considering the effect of various input parameters on certain performance measures using Taguchi's orthogonal array experimental design on DSS 2205.The comparison of Activated TIG welding with TIG welding has been investigated.

- Time and current has the major effect on the tensile strength, tensile strength is maximum at 180 sec and 250 amps, but at low gas flow rate.
- Hardness is mainly effected by current and hardness is maximum at 250 amps, 150 sec and 6 L/min.
- From experimental number 5 it was observation the optimum process parameters are time 150 sec, current 250 amps, gas flow 5 L/min and 2.4mm electrode diameter where tensile strength (723 N/mm^2) and Rockwell hardness number is 98.
- In Activated TIG welding depth of penetration (91.6%) and depth to width ratio is high compared to TIG welding.

Acknowledgment

The authors wish to thanks to Mechanical Engineering De-partment, UIET,MDU for sup-porting my work.

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